

Marine Monitoring



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Using oceanic time series from CMEMS Global Reanalyses: practical I Ocean Heat Content

Training prepared by:

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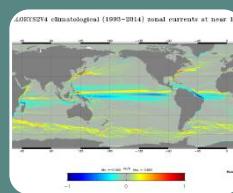
¹Mercator Ocean, France

²Mercator Ocean / CELAD, France

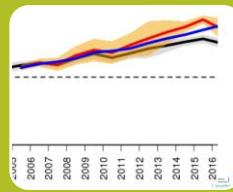


Overview

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GREP : a global 1993-2017 multi-reanalysis ensemble product at ~25km and daily frequency



Ocean Monitoring Indicators and their robustness estimates



Hands on Ocean Heat Content computation





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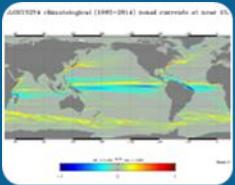


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GREP

Design and evaluation





Four reanalysis products using NEMO $\frac{1}{4}^\circ$

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- ✓ Use of **NEMO ORCA025 ($1/4^\circ$) + LIM & 75 vertical levels**
- ✓ Forced with **ERA-interim reanalysis**
- ✓ **Multivariate assimilation** of satellite SST, SLA, in situ T/S profiles + satellite Sea Ice concentrations
- ✓ oceanic initial conditions for coupled ocean-atmosphere seasonal (re)forecasts
- ✓ 1993-2017 ensemble mean, standard deviation and individual members for T, S, U, V, SSH, SIC available in July 2019 from **marine.copernicus.eu**
 - ✓ $\frac{1}{4}^\circ \times \frac{1}{4}^\circ$ daily frequency available in July 2019
 - ✓ $1^\circ \times 1^\circ$ monthly 1993-2016 already online
 - ✓ CMEMS open and free data policy

Approach based on ORA-IP
(Balmaseda et al , 2015) & multi
ORA (Xue et al, 2017)





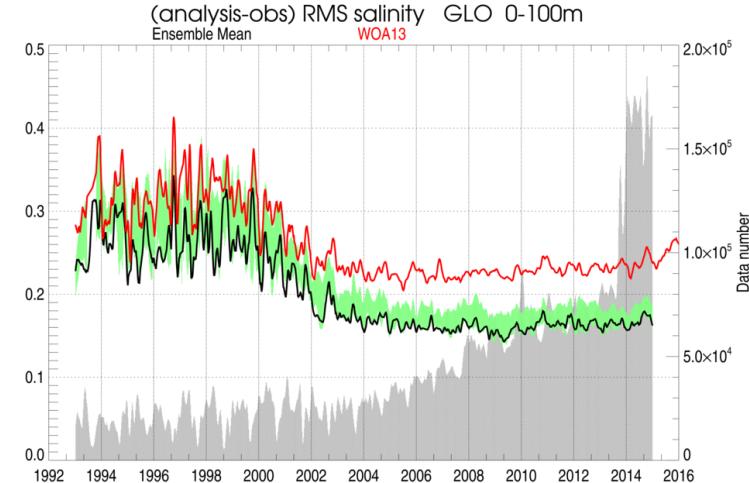
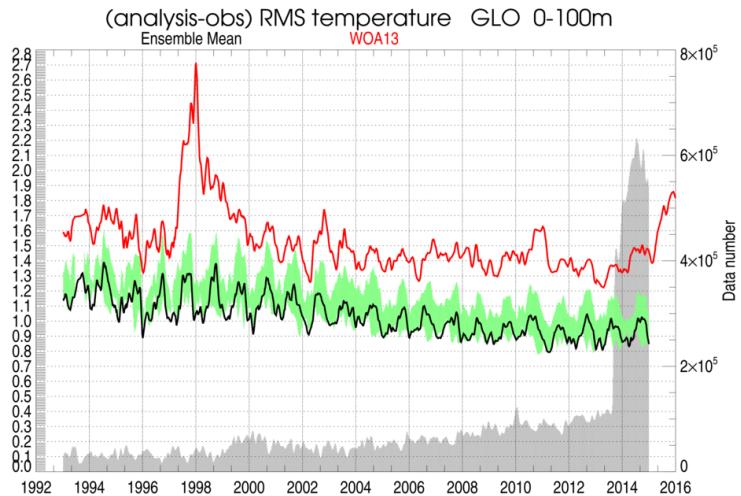
Four reanalysis products using NEMO ¼°

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Name / main reference	Production centre	Model version	Assimilation
GLORYS2V4 / Lellouche et al (2013) , Ocean Science	Mercator Océan	NEMO3.1 LIM2	SAM2 (SEEK) & 3Dvar bias correction 7-day assimilation window Hybrid MDT (obs+model)
GLOSEA5v13 / MacLachlan et al (2014) QJRMS	UK Met Office Hadley Center	NEMO3.4 CICE4.1	NEMOVAR (3Dvar) & bias correction 1-day assimilation window Hybrid MDT
C-GLORSv7 / Storto et al (2016) QJRMS	CMCC	NEMO3.6 LIM2	OceanVar (3Dvar) & bias correction 7-day assimilation window Model MDT
ORAS5 / Zuo et al (2017) ECMWF Tech Memo	ECMWF	NEMO3.4.1 LIM2	NEMOVAR (3Dvar) & bias correction 5-day assimilation window Model MDT



check of accuracy with respect to assimilated in situ T & S profiles



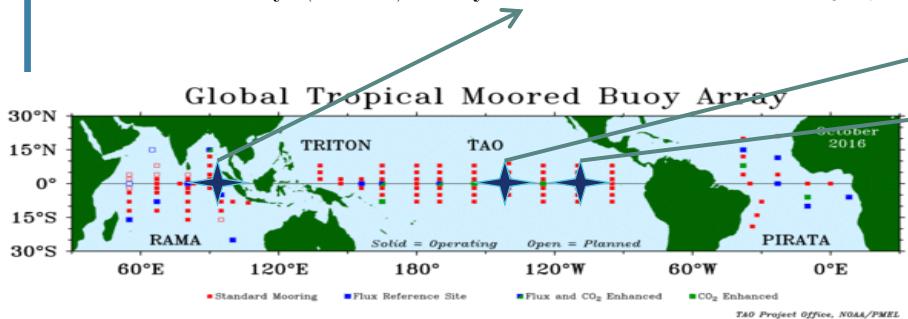
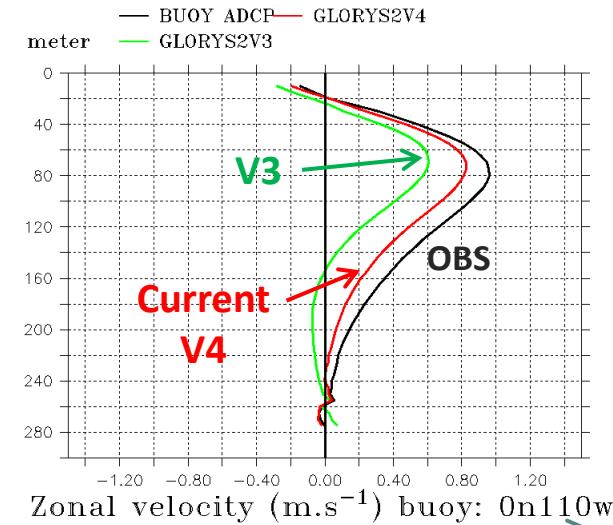
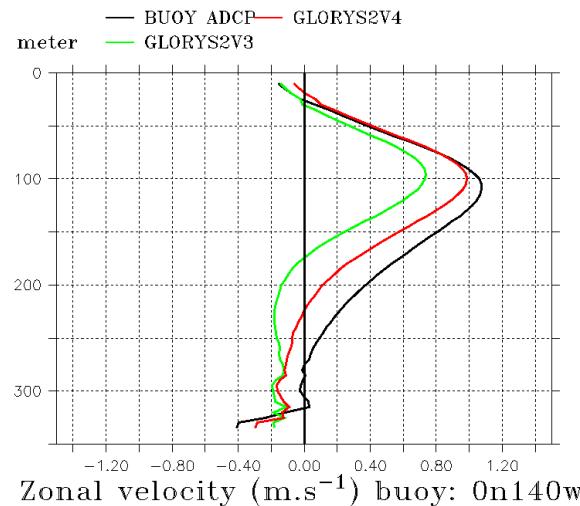
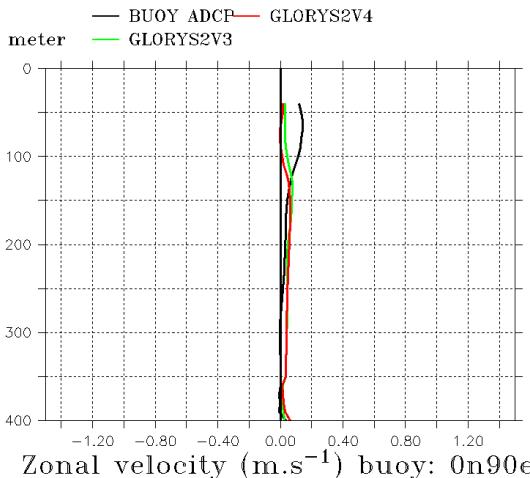
All individual members are evaluated with CLIVAR/GSOP/GODAE metrics



Evaluation of individual members: GLORYS

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Independent current meters from TAO/TRITON (in situ TAC)



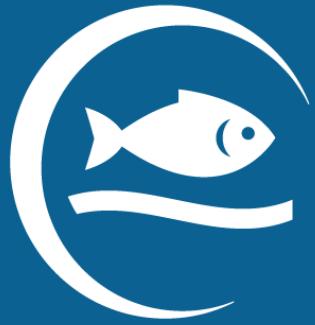
RMS < 0.3 m.s⁻¹

Underestimation of EUC (Equatorial Under Current)

*Continuous improvement since the beginning of GLORYS
-> data assimilation & mean dynamic topography*

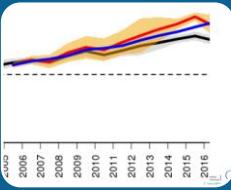


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Ocean state reporting with GREP



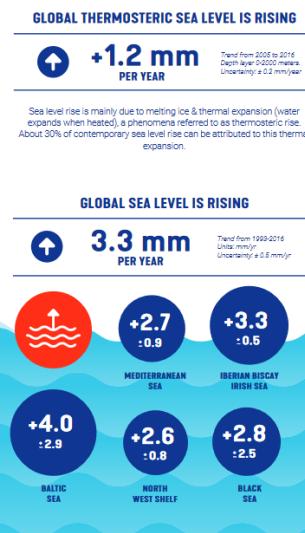


Ocean State Report

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Reference EU peer reviewed annual report (now #4 in preparation) based on CMEMS products



Online summary and indicators for

- EU and Member States policy makers
- Environmental agencies
- Regional Sea Conventions
- International organizations (IPCC, UN SDG14, OECD...)





Assessing robustness of OMIs with GREP

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Heat content using GREP ensemble mean + CORA + ARMOR3D
shading = where signal < spread

OCEAN HEAT CONTENT

Ocean Heat Content Monitoring Indicator

Anomalies and trends
Time series and maps

Multi-product approach:
global reanalyses and
reprocessed observations

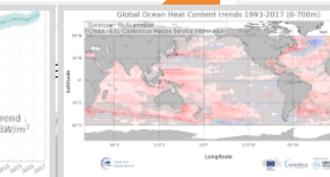
1993-2017

Time series can
be downloaded



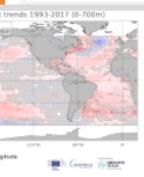
Global Ocean Heat Content
(0-700m)
1993-2017

MORE INFO



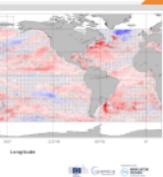
Global Ocean Heat Content
Trends 1993-2017 (0-700m)
1993-2017

MORE INFO



Global Ocean Heat Content
2017 Anomalies (0-700m)
2017 relative to the 1993-2014
reference

MORE INFO



Global Ocean Heat Content
2017 Anomalies (0-700m)
2017 relative to the 1993-2014
reference

MORE INFO

Online Ocean Monitoring Indicator **OMI**

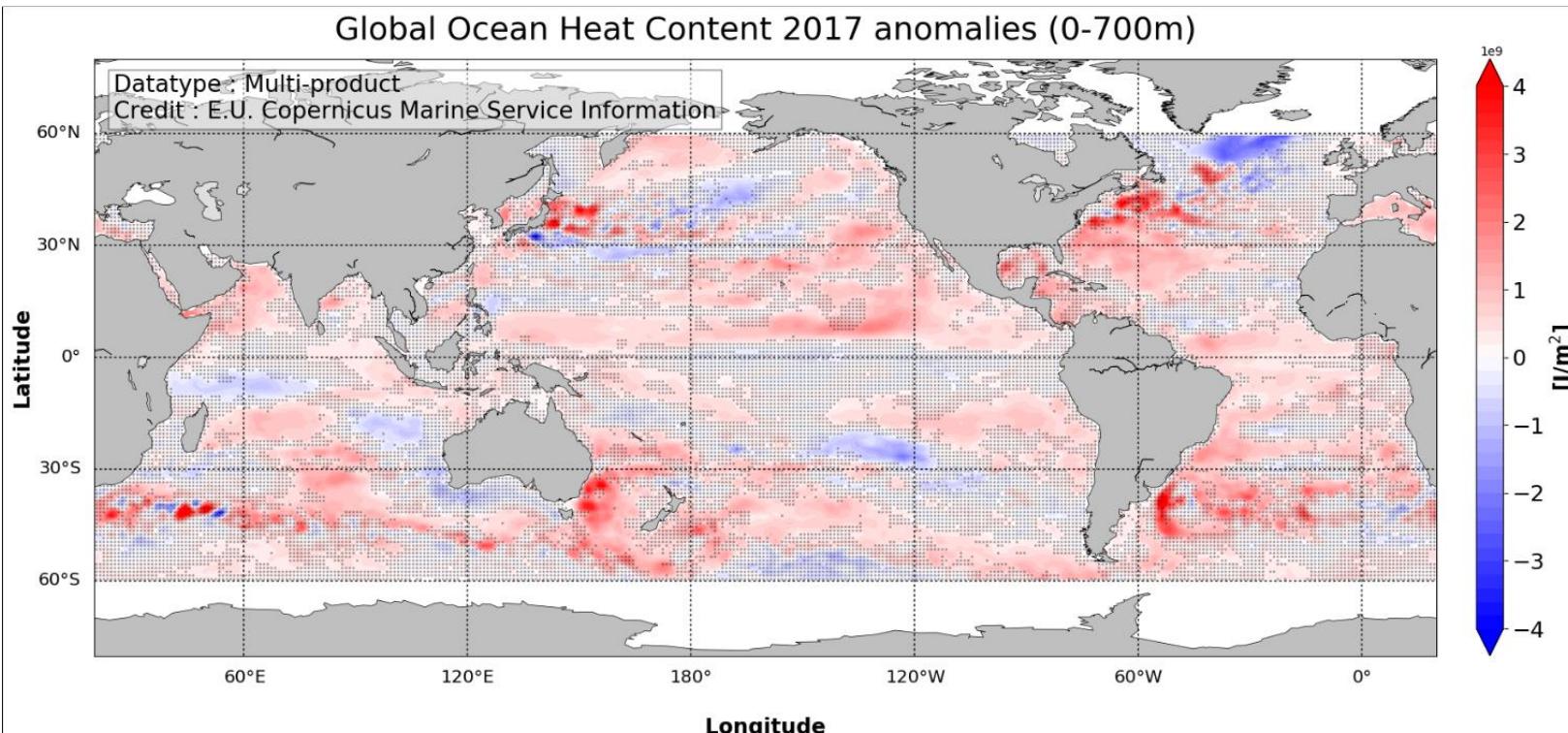


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Assessing robustness of OMIs with GREP

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European
Commission

Europe's eyes on Earth

INTERNATIONAL



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Hands on Ocean Heat Content computation





Open your navigator (any browser except chrome) and launch:
<https://bit.ly/2Lw8T5n>

If binder is still loading after more than 30s, refresh the page until you get this interface:

File Edit View Run Kernel Tabs Settings Help

https://hub.mybinder.org/user/copernicusmarin--copernicus-env-1howf1gv/lab

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- binder 6 days ago
- training_godae... 6 days ago
- 00-Getting-Started.ipynb 6 days ago
- README.md 6 days ago

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Table of Content

- Introduction
- Prerequisites

Click on
training_godae



Let's go !

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- 02-Developement-time-series-global-reanalysis-ens... 3 hours ago
- 03-ToGoFurther-mean-sea-level-altimetry.ipynb 3 hours ago

Launcher 00-Getting-Started.ipynb 01-Introduction-global-trend-heat-content-from-gl... Markdown Python 2

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Maps of regional Ocean Heat Content trends over the period 1993-2016

Note1: Execute each cell through the "RUN" button (or keyboard shortcut `Shift Enter`).

Note2: If, for any reason, the kernel is not working anymore, in the top MENU, click on "Kernel" and hit "Restart Kernel and Clear All Output...". Then, in the top MENU, click on "Run" and select "Run All Above Selected Cell".

Introduction

Global Ocean Heat Content (0-700m)

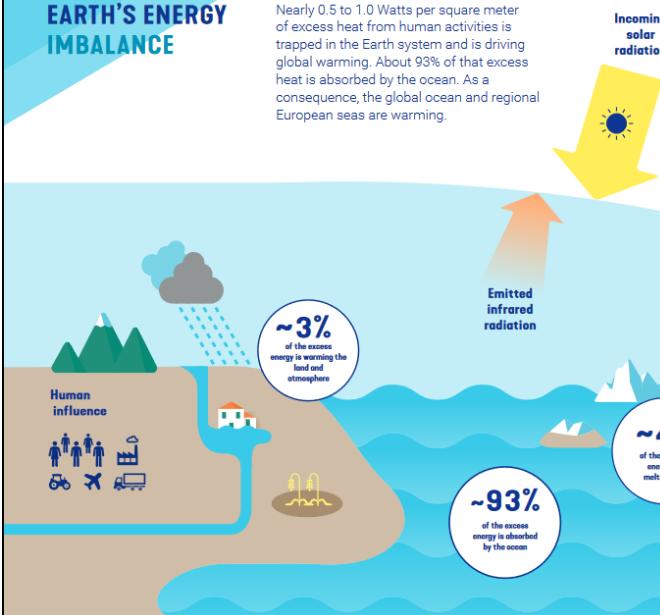




BLUE OCEAN

EARTH'S ENERGY IMBALANCE

Nearly 0.5 to 1.0 Watts per square meter of excess heat from human activities is trapped in the Earth system and is driving global warming. About 93% of that excess heat is absorbed by the ocean. As a consequence, the global ocean and regional European seas are warming.



SEA LEVEL RISE

Sea level rise can seriously effect human populations in coastal and island regions and natural environments like marine ecosystems. Global mean and regional sea level is affected by natural climate variability, as well as by human-induced changes. Because of ocean warming and land ice mass loss, the sea level rises. Water expands when heated and about 30% of contemporary sea level rise can be attributed to this thermal expansion (i.e. thermosteric sea level).

OCEAN HEAT CONTENT is the total amount of heat stored in the ocean (from top to bottom). A warming ocean causes thermal expansion and contributes to contemporary sea level rise. Thermal stress can contribute to coral bleaching and infectious diseases, changes in ocean water layers, currents, and increased sea ice melt. Moreover, a warming ocean alters ocean currents and modifies air-sea interactions, affecting weather and climate patterns from local to global scales.

IN THE LAST QUARTER OF A CENTURY

GLOBAL THERMOSTERIC SEA LEVEL IS RISING



Trend from 2005 to 2015
Depth layer: 0-200 meters
Uncertainty: ± 0.2 mm/year

Sea level rise is mainly due to melting ice & thermal expansion (water expands when heated), a phenomena referred to as thermosteric rise. About 30% of contemporary sea level rise can be attributed to this thermal expansion.

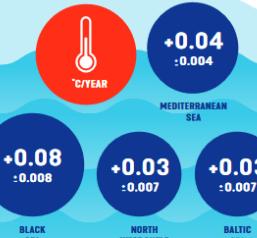
GLOBAL SEA LEVEL IS RISING



Trend from 1993-2015
Depth layer: 0-200 meters
Uncertainty: ± 0.5 mm/year

GLOBAL SEA SURFACE TEMPERATURE HAS INCREASED

Units: °C/year - Trend from 1993-2015



GLOBAL OCEAN HEAT CONTENT HAS INCREASED



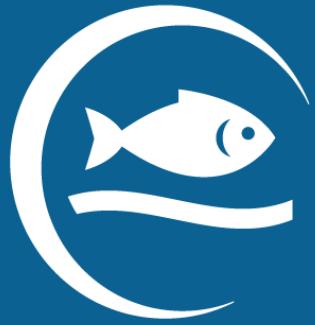
Trend from 1993-2015
Depth layer: 0-200 meters
Units: W/m², Uncertainty: ± 0.1 W/m²





Compare your results with the online OMI of heat content:

- What differences do you see between your results and the OMI? How can they be explained?
- Explore the regional signals, are they consistent with the regional trends as given in the Ocean State Report summary?



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Using oceanic time series from CMEMS Global Reanalyses: practical II Mean Sea Level trend

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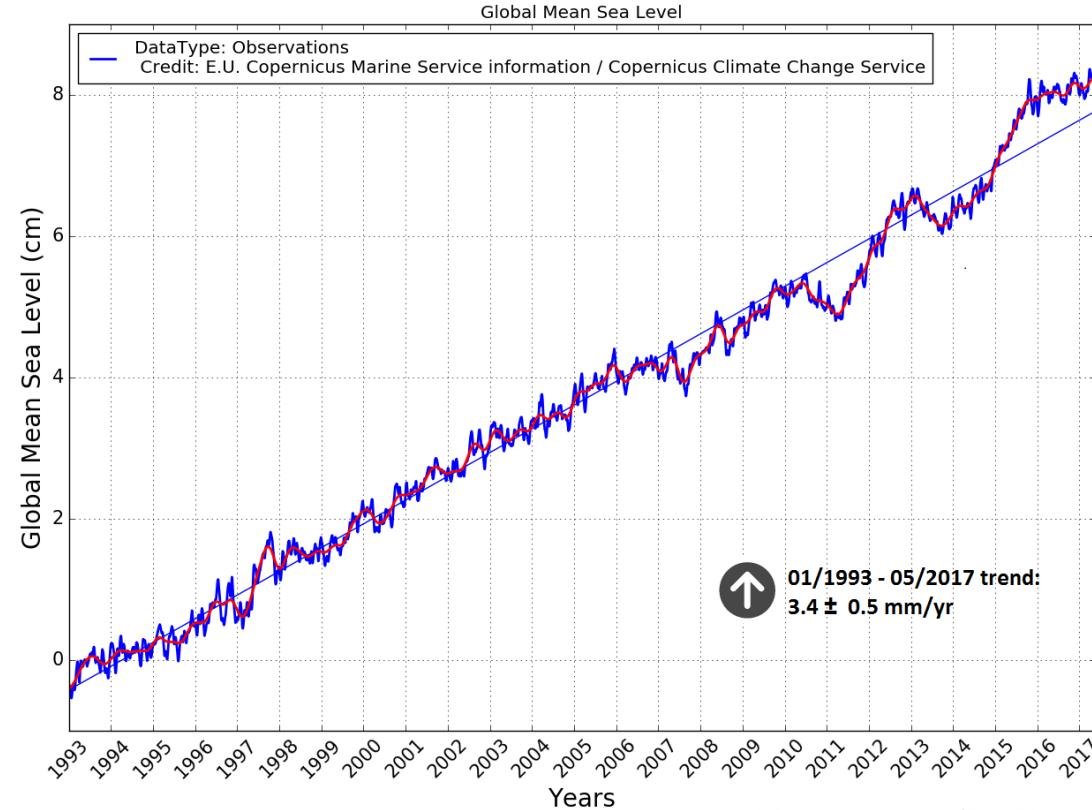


Mean Sea Level rise

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We'll try to
reproduce this
curve:

- What difference between your curve and this one?
- Explore the OMI documentation to understand where the differences come from
- Look at global and regional trends





```
df = pd.DataFrame(msl,index=tt)
```

```
plt.plot(df)
```

```
df_annual= df.rolling('365D').mean()
```

```
coefficients, residuals, _, _, _ = np.polyfit(x,msl,1,full=True)
```

```
coefficients[0]*12*1000
```

```
# trend in mm/year
```

```
coefficients, residuals, _, _, _ = np.polyfit(x,df_annual,1,full=True)
```

```
coefficients[0]*12*1000
```



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